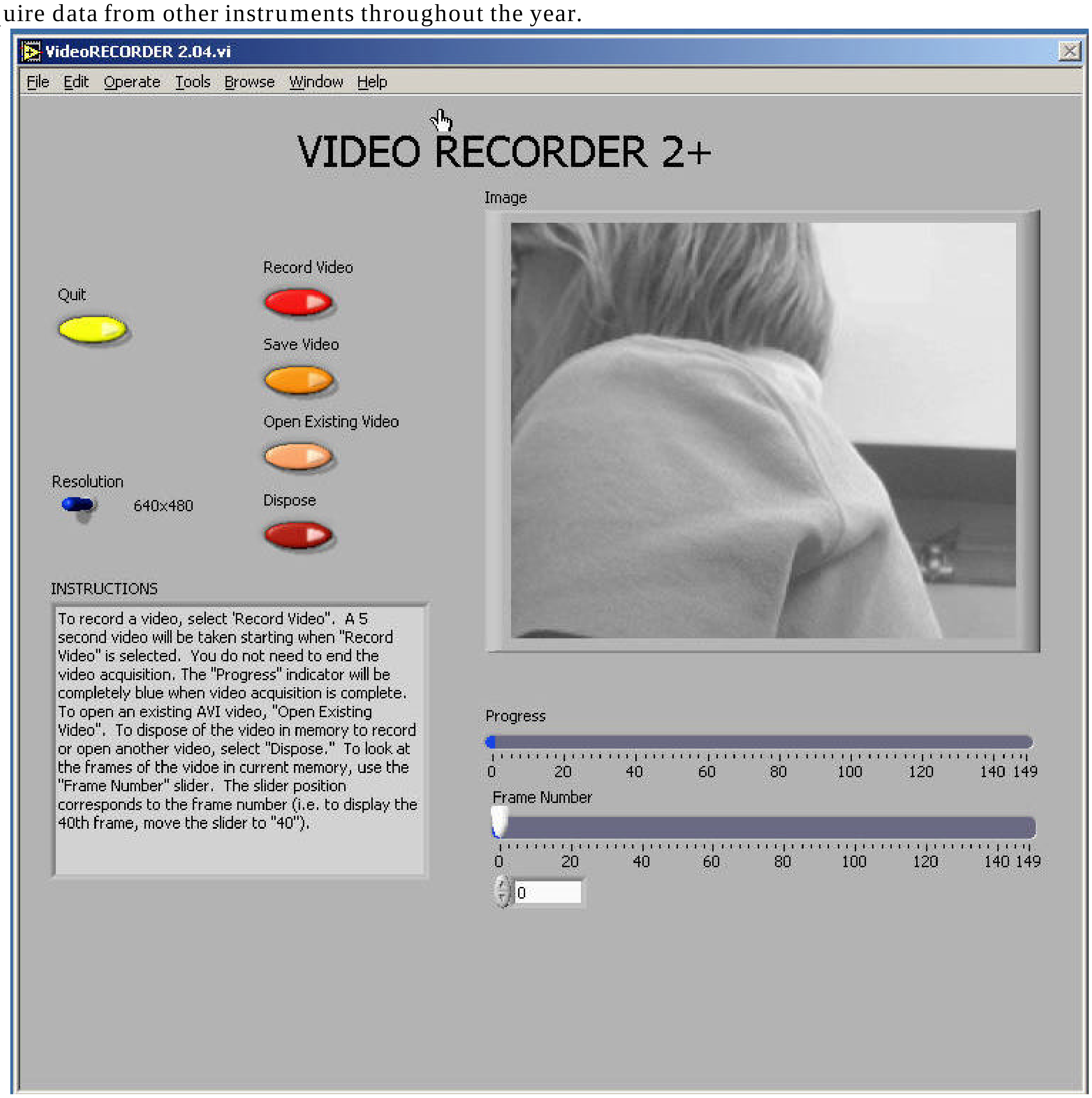
Appendix E: Software

Video Analysis of Motion

Analyzing pictures (movies or videos) is a powerful tool for understanding how objects move. Like most forms of data, video is most easily analyzed using a computer and data acquisition software. This appendix will guide a person somewhat familiar with WindowsNT through the use of one such program: the video analysis application written in LabVIEW™. LabVIEW™ is a general-purpose data acquisition programming system. It is widely used in academic research and industry. We will also use LabVIEW™ to acquire data from other instruments throughout the year.



Using video to analyze motion is a two-step process. The first step is recording a video. This process uses the video software to record the images from the camera and compress the file. The second step is to analyze the video to get a kinematic description of the recorded motion.

(1) MAKING VIDEOS

After logging into the computer, open the video recording program by double clicking the icon on the desktop labeled *VideoRECORDER*. A window similar to the picture on the previous page should appear.

If the camera is working, you should see a "live" video image of whatever is in front of the camera. (See your instructor if your camera is not functioning and you are sure you turned it on.) By adjusting the lens on the video camera, you can alter both the magnification and the sharpness of the image until the picture quality is as good as possible.

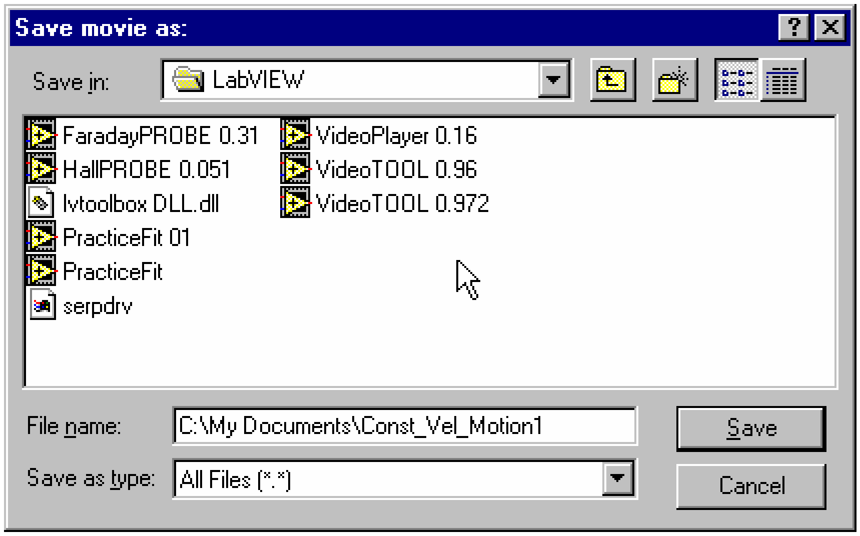
The controls are fairly self-explanatory; pressing the *Record Video* button begins the process of recording a 5-second video image. While the video is recording, the blue *Progress* bar beneath the video frame grows. Once you have finished recording, you can move through the video by dragging the *Frame Number* slider control. If you are not pleased with your video recording, delete it by pressing the *Dispose* button.

You may notice that the computer sometimes skips frames. You can identify the dropped frame by playing the video back frame by frame. If the recorded motion does not appear smooth or if the object moves irregularly from frame to frame, then frames are probably missing. If the computer is skipping frames, speak with your instructor.

While you are recording your video, you should try to estimate the kinematic variables you observe, such as the initial position, velocities, and acceleration. The time with the unit of second is shown in the *VideoRECORDER* window, in the box below the *Frame Number* slider. These values prove very useful for your prediction equations. Be sure to record your estimates in your journal.

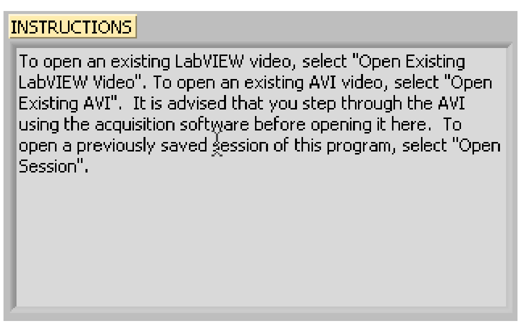
Once you have recorded a satisfactory video, save it by pressing the *Save Video* button. You will see a *Save* window, as shown on the next page.

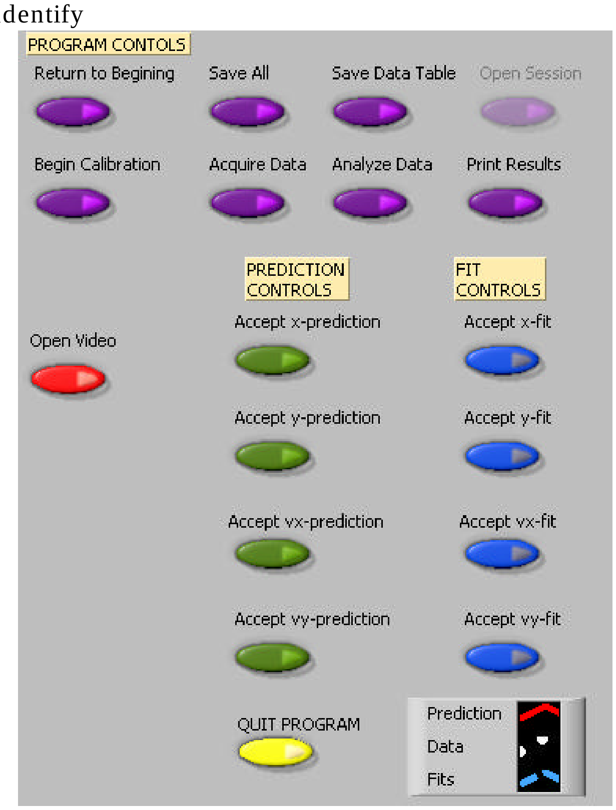
To avoid cluttering the computer, you will only be able to save your video to certain folders on the hard disk. One such folder is the *My Documents* folder located on the C drive. You should check with your lab instructor for the most suitable place to save your video. In the *File name* box, you should enter the location of the folder in which you wish to save your video followed by the name that you wish to give to your video. This name should be descriptive enough to be useful to you later (see the picture for an example).



(2) ANALYSIS BASICS

Open the video analysis application by clicking the icon labeled *VideoTOOL*, which is located on the desktop. You should now take a moment to identify several elements of the program. The two most important of these are the *Program Controls* panel shown to the right and the *Instructions* box shown below.





These two elements of the analysis program work in tandem. The *Instructions* box will give you directions and tasks to perform. It will also tell you when to select a control in the *Program Controls* panel. After you select a control, it will "gray out" and the next control will become available. If you make a mistake, you cannot go backwards! You would have to quit your analysis and reopen the video to begin afresh.

You print and / or quit the video analysis from the *Program Controls* panel. You also have the option to save the data to continue later, or to save a data table.

Be careful not to quit without printing and saving your data! You will have to go back and analyze the data again if you fail to select *Print Results* before selecting *Quit Program* or *Return to Beginning*. Also be sure to save the data (*Save All*) and save the data table (*Save Data Table*).

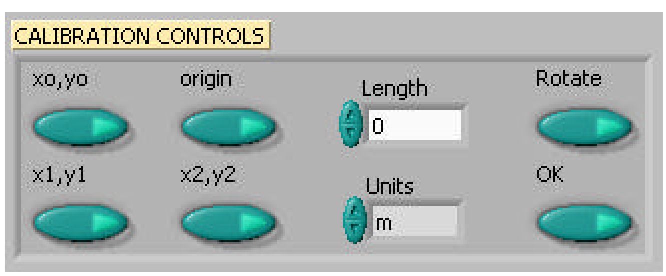
CALIBRATION

While the computer is a very handy tool, it is not smart enough to identify objects or the sizes of those objects in the videos that you take and analyze. For this reason, you will need to enter this information into the computer. If you are not careful in the calibration process, your analysis will not make any sense.

After you open the video that you wish to analyze and select *Begin Calibration* from the *Program Controls* panel you will be advised in the *Instructions* box "To begin Calibration, advance the video to a frame where the first data point will be taken. The time stamp of this frame will be used as the initial time." To advance the video to where you want time t=0 to be, you need to use the video control buttons, shown below. This action is equivalent to starting a stopwatch.

Practice with each button until you are proficient with its use. When you are ready to continue with the calibration, locate the object you wish to use to calibrate the size of the video. The best object to use is the object whose motion you are analyzing, but sometimes this is not easy. If you cannot use the object whose motion you are analyzing, you must do your best to use an object that is in the plane of motion of your object being analyzed.

Follow the direction in the *Instructions* box and define the length of an object that you have measured for the computer. Once this is completed, input the scale length with proper units in *Calibration Controls* box (shown below). Read the directions in the *Instructions* box carefully. Enter the scale length, and then use the arrows to select the units you are using.



Lastly, decide if you want to rotate your coordinate axes. If you choose not to rotate the axes, the computer will choose the lower left-hand corner of the video to be the origin with positive x to the right and positive y up. If you choose to rotate your axis, follow the directions in the *Instructions* box carefully. Your chosen axes will appear under the *Calibration Controls* box. This option may also be used to reposition the origin of the coordinate system, should you require it.

Once you have completed this process, select "OK" from the *Calibration Controls* box.

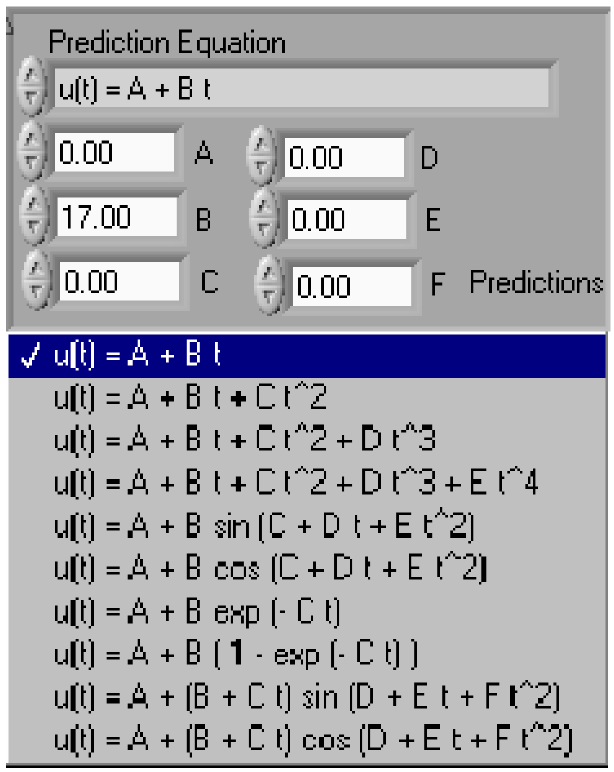
ANALYSIS PREDICTIONS

This video analysis relies on your graphical skills to interpret the data from the videos. Before doing your analysis, you should be familiar with both Appendix C: Graphing and Appendix B: Uncertainties.

Before analyzing the data, enter your prediction of how you expect the data to behave. This pattern of making predictions before obtaining results is the only reliable way to take data. How else can you know if something has gone wrong? This happens so often that it is given a name (Murphy's Law). It is also a good way to make sure you have learned something, but only if you stop to think about the discrepancies or similarities between your prediction and the results.

In order to enter your prediction into the computer, you first need to decide on your coordinate axes, origin, and scale (units) for your motion. Record these in your lab journal.

Next you will need to select the generic equation, u(t), which describes the graph you expect for the motion along your x-axis seen in your video. You must choose the appropriate function that matches the predicted curve. The analysis program is equipped with several equations, which are accessible using the pull-down menu on the equation line (shown to the right).



You can change the equation to one you would like to use by clicking on the arrows to the left of the equation in the *Prediction Equation* command box, shown to the right. Holding down the mouse button will give you the menu also shown to the right.

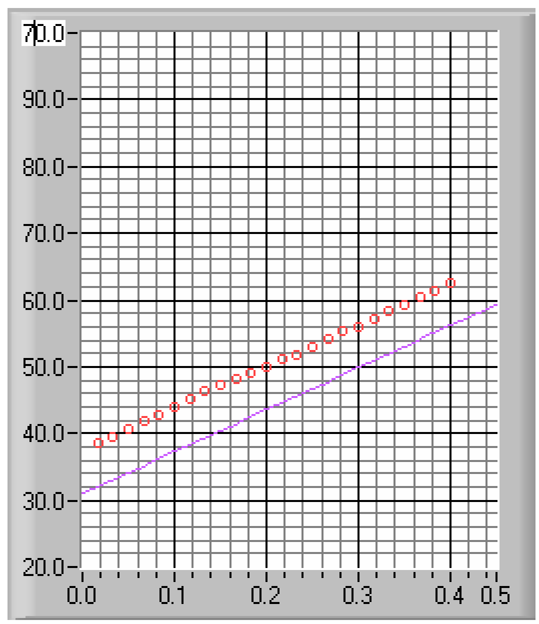
After selecting your generic equation, you next need to enter your best approximation for the parameters A and B and C and D where you need them. If you took good notes of these values during the filming of your video, inputting these values should be straightforward. You will also need to decide on the units for these constants at this time.

Once you are satisfied that the equation you selected for your motion and the values of the constants are correct, click "*Predictions*" in the *Prediction Equation* command box. Your prediction equation will then show up on the graph on the computer screen. If you wish to change your prediction simply repeat the above procedure. When you are satisfied, select the *Accept x- (or y-) prediction* option from the *Program Controls* panel. Once you have done this you cannot change your prediction except by starting over. Repeat this procedure for the Y direction.

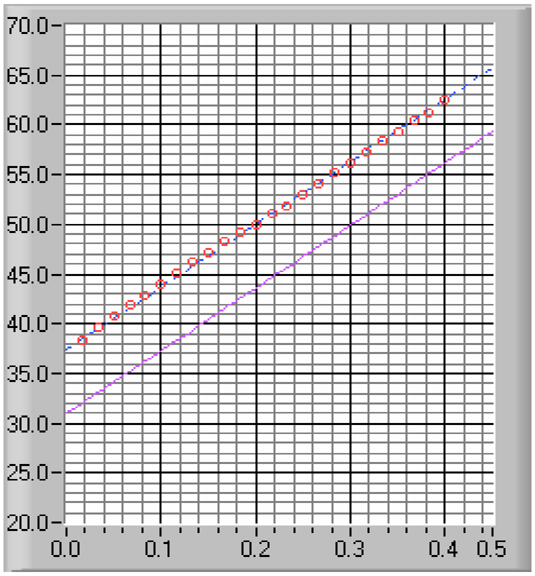
DATA COLLECTION
To collect data, you first need to identify a very specific point on the object whose motion you are analyzing. Next move the cursor over this point and click the green *Accept Data Point* button in *VideoPLAYER* window. The computer records this position and time. The computer will automatically advance the video to the next frame leaving a mark on the point you have just selected. Then move the cursor back to the same place on the object and click *Accept Data Point* button again. So long as you always use the same point on the object, you will get reliable data from your analysis. This process is not always so easy especially if the object is moving rapidly. Because the camera has an interlaced scan of the image, it actually gives you two images. For a rapidly moving object, these images split apart. You need to keep track of which image you are measuring for each picture frame. The data will automatically appear on the appropriate graph on your computer screen each time you accept a data point. If you don't see the data on the graph, you will need to change the scale of the axes. If you are satisfied with your data, choose *Analyze Data* from the *Program Controls* panel.

FITTING YOUR DATA
Deciding which equation best represents your data is the most important part of your data analysis. The actual mechanics of choosing the equation and constants is similar to what you did for your predictions.

First you must find your data on your graphs. Usually, you can find your full data set by adjusting the scales of your X-motion and Y-motion plots. This scaling is accomplished by entering the appropriate maximum and minimum values on the vertical axis (as shown to the right) as well as adjusting the time scale.

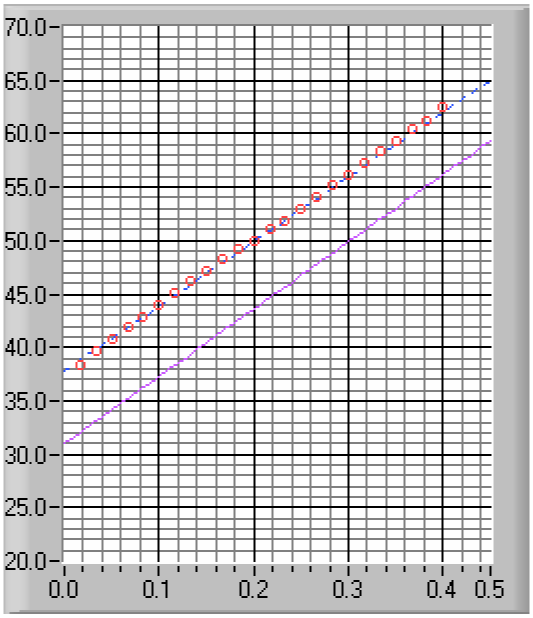


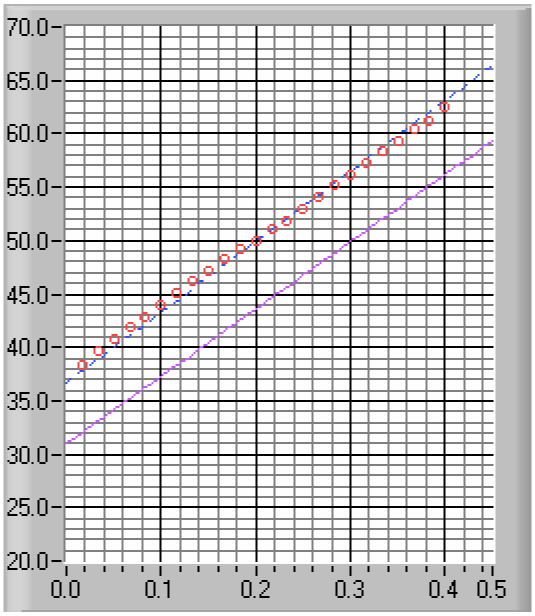
Secondly, after you find your data, you need to determine the best possible equation to describe this data. After you have decided on the appropriate equation, you need to determine the constants of this equation so that it best fits the data. Although this can be done by trial and error, it is much more efficient to think of how the behavior of the equation you have chosen depends on each parameter. Calculus can be a great help here.



As an example of a completed determination of the equation, the X-motion plot above shows both the predicted line (down) and the line that best fits the data (through the circles). Be sure to record the values of your parameters in your journal before you go on to the next stage.

Lastly, you need to estimate the uncertainty in your fit by deciding the range of other lines that *could* also fit your data. This method of estimating your uncertainty is described in Appendix C. Slightly changing the values for each constant in turn will allow you to do this quickly. For example, the X-motion plots below show both the predicted line (down) and two other lines that also fit the data (near the circles).





After you have found the uncertainties in your constants, return to your best-fit line and use it as your fit by selecting *Accept x- (or y-) fit* in the *Program Controls* panel.

MEASURING CONSTANT MAGNETIC FIELD
(THE HALL PROBE APPLICATION)

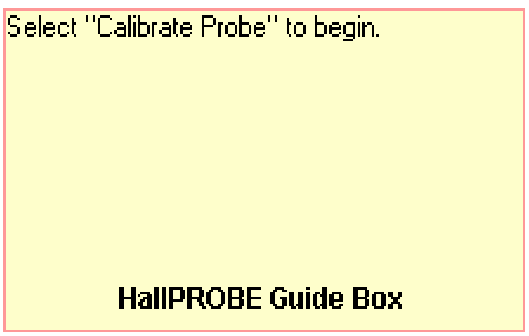
Basics

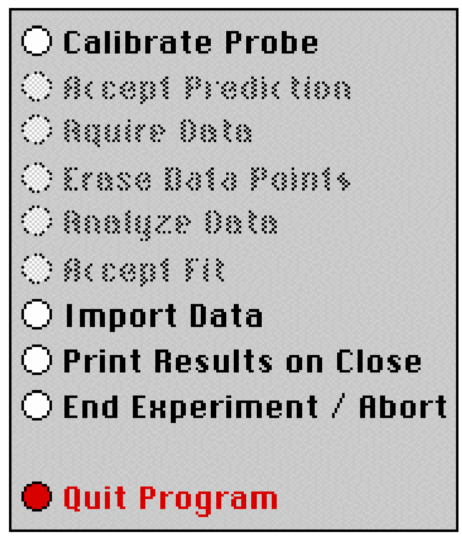
Before you begin, you should ensure that you have read the relevant sections of Appendix D to familiarize yourself with the equipment.

The software package that works in tandem with your magnetic field sensor is written in LabVIEW™. It allows you to measure and record magnetic field strength as a function of a number of different variables.

After logging into the computer, execute the application by double clicking the "HallPROBE" icon on the desktop.

Before you start using the program, you should take a moment to identify several key elements. The two most important of these are the Command Panel, shown to the right, and the Guide Box, shown below.





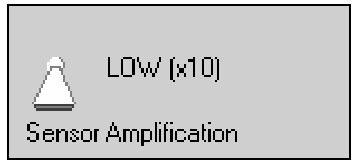
The Guide Box will give you directions and tasks to perform. It will also tell you when to select a command in the Command Panel. After selecting a command, it will "gray out" and the next command will become available.

You can also print and / or quit from the Command Panel or abort your analysis and try again.

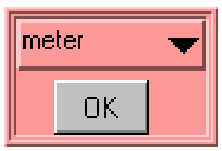
The primary data output you get is by printing your results, so be careful not to quit without printing or exporting your data.

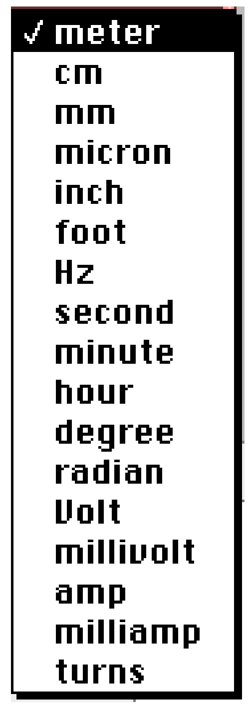
Calibration

The first command is to calibrate the Magnetic Field Sensor. Before selecting this command, you need to decide whether you require high or low amplification. Switch the amplifier box to the appropriate setting also set the amplification switch on the screen to the same setting. The amplification switch on the screen toggles between the two settings by clicking it with the mouse. The two amplification settings are shown below:



After selecting the "Calibrate Probe" command, you will be asked to do *two* tasks. Firstly, you will need to choose the quantity on the x-axis of your data graph. This is accomplished by moving the mouse cursor over to the word "meter" in the red-colored area (shown below) and then pressing the mouse button.





You should get a list of choices as shown to the right. By selecting any of these units, you will be making a choice about what you wish to measure. For example, if you choose to use "cm”, you will make a graph of magnetic field strength as a function of distance (B vs. x). It is likely you will want to choose a small unit (cm’s or mm’s) to measure the distance in, since many magnetic fields are not very strong over long distances Selecting "degree" will make a plot of magnetic field strength as a function of angle (B vs. θ). Click "OK" when you are ready to proceed.

Secondly, you will need to eliminate the effect of the background magnetic fields. This process is called "zeroing the Hall probe" in the Guide Box. **Place the magnetic field sensor wand in the position you would like to take your measurement, but be sure that there are no magnets nearby.** Note that power supplies and computers generate magnetic fields, so it is a good idea to keep away from them! When you are ready, select the "First Calibration Value" as shown below. Now rotate the wand 180 degree around its long axis (similar to rolling a pencil) and select "Second Calibration Value."

The calibration process is now complete.

Predictions

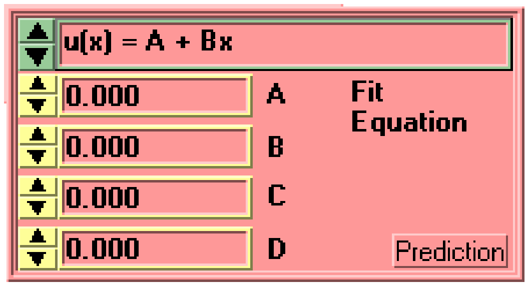
This type of analysis relies on your graphical skills to interpret the data, so you should be familiar with both Appendix D: *Graphing*, and Appendix C: *Uncertainties.*

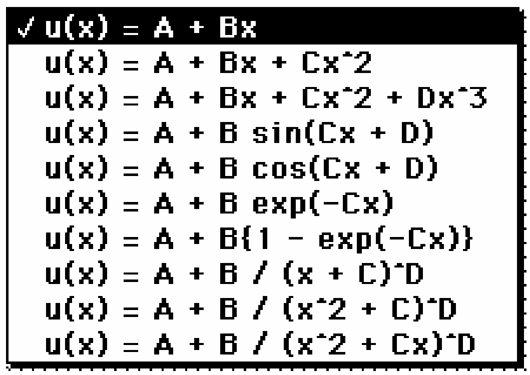
The first task is to enter your prediction of the mathematical function you expect to represent your data. Making a prediction before taking data is the best way to determine if anything is going wrong (remember Murphy's Law). It's also a good way to make sure you have learned something, but only if you stop to think about the discrepancies or similarities between your prediction and the results.

In order to enter your graphical prediction, you first need to decide on your coordinate axes and scale (units) for your measurements. *Record these in your lab journal.*

Next, you will need to select the generic equation, u(x), which describes the graph you expect for the data. Clicking the equation currently showing in the box will bring up a list of equations to choose from; see the diagrams to the right.

After selecting your generic equation, you next need to enter your best approximation for the parameters A, B, C, and / or D. These values should come directly from your prediction equation you did for class. As you enter these values, you should see the red line in the "Plot" box changing.





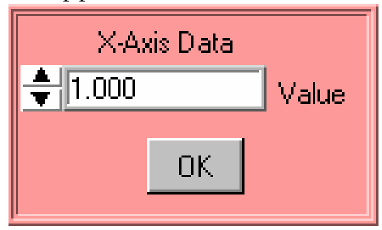
Once you are satisfied that the equation you selected and the values of the constants are correct, select the *Prediction* button in the Fit Equation command box. Your prediction equation will then show up on the graph on the computer screen. If you do not see the curve representing your prediction, change the scale of the graph axes or use the *AutoScale* feature (see Finding Data below). If you wish to change your prediction, simply repeat the above procedure. When you are satisfied, select the *Accept Prediction* option from the Command Panel. Once you have done this you cannot change your prediction except by starting over.

Exploration

After you have entered your prediction, you can explore the limitations of your magnetic field sensor before you take data. The value of the magnetic field strength is displayed directly under the Guide Box. When you are ready to take data, select *Acquire Data* from the Command Panel.

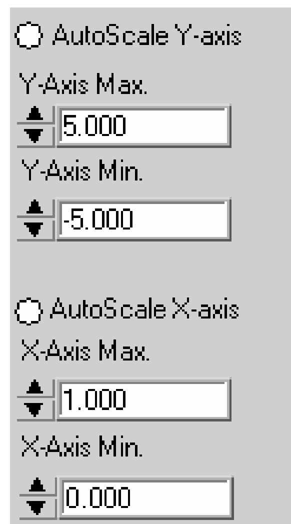
Data Acquisition

Collecting data requires that you enter the x-axis data each time the computer reads in a value for the magnetic field strength. You enter this data using the panel shown to the right. For every x-axis data value you enter, the analysis program will record the magnetic field strength in gauss on the y-axis of the "Plot". Press "OK" to collect the next data point. Each data point should appear on the graph on the computer screen as you take it. If it doesn't, adjust the scales of your graph axes or use the *AutoScale* feature (see Finding Data below). If you are satisfied with your data, choose *Analyze Data* from the Command Panel.



Finding Data on the Graph

You can find your data on the graph by adjusting the scales of your X-axis and Y-axis plots. This scaling is accomplished by entering the appropriate values into the "Y-Axis Max." and "Y-Axis Min." fields (as shown to the right) as well as adjusting the "X-Axis Max." and "X-Axis Min." fields (also shown to the right). If you cannot locate your data, you can select both "AutoScale Y-axis" and "AutoScale X-Axis" to let the program find the data for you. You can then adjust your axis scales to give you a convenient graph for analysis. Be careful, the AutoScale option will often set the scales in such a way that small fluctuations in the data are magnified into huge fluctuations.



Data Fits

Deciding which equation best fits your data is the most important part of using this analysis program. While the actual mechanics of choosing the equation and parameters is similar to what you did for your predictions, fitting data is somewhat more complicated.

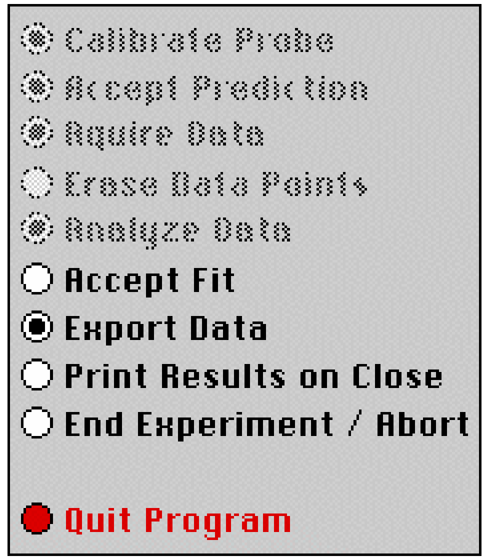
By looking at the behavior of the data on the graph, determine the best possible function to describe this data. After you have decided on the appropriate equation, you need to determine the constants of this equation so that it best fits the data. Although this can be done by trial and error, it is much more efficient to think of how the behavior of the equation you have chosen depends on each parameter. Calculus can be a great help here. *This can be a time-consuming task, so be patient.*

Now you need to estimate the uncertainty in your fit by deciding the range of other lines that *could* also fit your data. This method of estimating your uncertainty is described in Appendix D. Slightly changing the values for each constant in turn will allow you to do this quickly.

After you have computed your uncertainties, return to your best-fit line and use it as your fit by selecting *Accept Fit* in the Command Panel.

Importing / Exporting Data

After you have selected *Analyze Data*, it is possible to save your data to the computer's hard drive. This feature can come in handy if you need to analyze your data at a later date or if you want to re-analyze your data after you have printed it out.



To save your data, simply select *Export Data* (as shown to the right) and follow the instructions in the windows. Your file will be saved to your section’s lab folder. To retrieve this file, restart *HallPROBE* from the desktop and select *Import Data.*

Last Words

These directions are not meant to be exhaustive. You will discover more features as you analyze more data. Be sure to record these features in your lab journal.